Review of the Connecticut Department of Energy and Environmental Protection, Fisheries Division, 2003 *Kinneytown Dam Fish Passage Facility Evaluation Study* and cumulative daily fish passage counts from 2000-2020

September 3, 2021

Bill Lucey[a], John Waldman[b], Gwen MacDonald[a], Kevin Zak[c], Jon Vander Werff[a], Gavin Kreitman[a]

[a] Save the Sound, [b] Queens College, CUNY, [c] Naugatuck River Revival Group

Executive Summary

The fish passage facility at the Kinneytown Dam on the Naugatuck River is located in Seymour CT. The facility was constructed in 1999 and has operated since 2000. In 2003, the Connecticut Department of Environmental Protection's published an assessment evaluating the first three years of fish ladder operations: ***Kinneytown Dam Fish Passage Facility Evaluation Study***. This analysis expands on those findings.

In order to understand how well Kinneytown Dam fish passage facility is working and its role in the restoration of anadromous fish within the watershed, daily fish count data from 2000 to 2020 was analyzed to evaluate the relationship between stream discharge and daily passage of multiple species of riverine fish. Overall, 14 years of daily fish passage data were reviewed. The review looked at two time-periods: (1) the full spring migration between April 1 to July 1 of each year; and (2) the peak migration from April 8 to May 19. A frequency analysis indicates peak fish passage through the ladder occurs for six weeks from the second week in April to the third week in May with this period encompassing 75% of fish observed passing through the ladder. Fish passage essentially ceases under 200 cfs when flows are too low to run the Unit 1 turbine; fish passage begins to decrease around 473 cfs and ceases when flows are over 1000 cfs.

Both high and low flow conditions cause water to overtop the spillway, creating false attraction to the base of the dam away from the fish passage entrance. However, random spillway activation can occur at any flow depending on hydropower management. Favorable passage flows occurred on average only 39% of the time during the peak fish passage period for the years 2000-2020, with annual rates varying widely ranging from 0% to 83%. Cumulative fish counts from 2000-2020 for the entire spring migration period (April 1 to July 1) were compared to stream flow. Stream discharge rates from 201-700 cfs accounted for 78% of all fish counted at the ladder exit. Discharges between 201-500 cfs accounted for 60% of all fish counted, with peak passage occurring between flows of 201-400 cfs, which accounted for 47.5% of all fish passed, indicating this latter discharge range as the easiest for fish to ascend the ladder and exit. For the years 2000 to 2020, the average annual combined total for American Shad (*Alosa sapidissima*), Blueback Herring (*Alosa aestivalis*), and Alewife (*Alosa pseudoharengus*) combined was 12.5 individual fish per year from April 1 to July 1.

I. Introduction

Kinneytown Dam is located in Seymour, Connecticut, on the Naugatuck River. In 2003, the Connecticut Department of Energy and Environmental Protection (CTDEEP) Fisheries Division published an assessment of the fish ladder at the Kinneytown Dam four years after its 1999 construction entitled: ***2003 Kinneytown Dam Fish Passage Facility Evaluation Study*** ("*2003 Kinneytown Evaluation Study*" or the "Study"). The evaluation study utilized three years of fish passage observations from 2000 to 2002 The study was not an effectiveness analysis which would have determined what portion of migrating fish below the dam successfully ascend the ladder to continue upstream. The Study focused on which individuals of certain species succeeded in passing the ladder and made the assumption that if the species was detected, the ladder was passable. The Study also recorded fish observations in the bypass reach and in the ladder, as well as water elevations related to the ladder function. This is an appropriate first step in an efficiency assessment but does not identify if enough individuals pass to state that the ladder is successful. Annual daily fish observations were continued by CTDEEP until the present with the exception of 2009 and 2017. Though the *2003 Kinneytown Evaluation Study* does not describe an "efficiency" analysis, or the percentage of a total run passing within a given period of time, it provides valuable information on the numbers of anadromous and non-anadromous species that physically ascend the fishway and make it to the counter. No data is available to measure the number of fish that arrived in proximity to or entered the fishway, but did not make it to the counter.

Our study looks at both the *2003 Kinneytown Evaluation Study* and subsequent years of fish ladder counts to evaluate how well the facility is passing fish; it is not an efficiency rating. The review includes observations on hydropower generation, stream discharge, run timing, as well as ladder usage for specific species of fish. The results provide a backdrop for how well the State of Connecticut is meeting the potential for achieving its fish restoration goals for the Naugatuck River. Each year was analyzed for the entire migration period from April 1 to July 1 for days when daily ladder counts were available, as well as the peak migration period from April 8 to May 19. These datasets allow for fine-scale comparisons between daily mean high flows from the USGS Beacon Falls Stream Gauge, which is approximately six river miles upstream on the Naugatuck River, and fish passage numbers recorded on video at the ladder.

The *2003 Kinneytown Evaluation Study* identified passage patterns which highlight the ladder limitations primarily caused by both the project's discharge and geography of the hydropower site, which creates naturally "flashy" flow regimes. The Study also discusses riverine water quality and river debris blockage issues. Generally, the conclusions reached in the *2003 Kinneytown Evaluation Study* regarding discharge limitations that were associated with daily fish passage use held true throughout the following years of fishway counts. The Study concluded that fish passage efficiency began to decline at 500 cfs and was almost non-existent during flows below 200 cfs or above 1000 cfs. However, it is unclear the extent by which dam operations affect the problem of false attraction. Detailed spillway activation data was collected by CTDEEP in 2002 for the evaluation. During the 2002 observation period, there were 23 days of active spill into the bypass; however, 11 of those days were spilling below 500 cfs in what is considered optimal discharge for ladder use (211 cfs to 474 cfs) and at least partly attributed to the shutting down of the hydropower turbine.

II. Methods

The primary assessment variables utilized for evaluating the general effectiveness of the facility consisted of daily fish passage observations in relation to USGS stream gauge data.

The fish species comparison to discharge was done both in an aggregate of all species recorded and with river herring (alewife and blueback herring) and American and gizzard shad as a separate grouping. Given the low numbers of river herring and shad utilizing the fish ladder over the time period analyzed it was easier to detect the effects of discharge on fish passage using all the fish species in aggregate.

The discharge period used for this analysis is April 1 to July 1. The CTDEEP Fisheries Division provided daily fish counts for this period in 2001-2020 for this analysis, with the exception of 2000, 2008, 2009, 2010, 2014, 2015, and 2017 for which annual counts were provided (2009 and 2017 were not monitored). The first date of fish passage observations varied from year to year with an average start time of April 9th resulting in a total of 1,132 days of fish counts to compare with daily high flow discharge records. In some years the fish ladder observations were continued into July, though no American Shad (*Alosa sapidissima*), Blueback Herring (*Alosa aestivalis*), or Alewife (*Alosa pseudoharengus*) (species collectively referred to alosines), or gizzard shad (*Dorosoma cepedianum*) were initially observed in July. Therefore, the analysis was restricted to the months of April, May, and June, which encompasses the typical spring run timing.

The majority of anadromous fish pass over the Kinneytown Dam between April and May. To increase the likelihood that fish were present and attempting to ascend the ladder, flow-to-fish passage comparisons were focused on during this peak migration period which improves the likelihood that when no fish are counted at the video monitoring station it is a result of inability or lack of desire to pass, not that fish were absent. The peak migration timing was determined by observing the cumulative annual daily runs and selecting the period which passed the highest percentages of fish. Peak migration was determined to run from April 8 to May 19.

Fish ladder counting operations began at different times depending on the year. Table 1 describes the available years of data and the annual number of daily observations used to compare daily high flows from the USGS gauge.

Table 1. Number of daily observations by year.

Year	Spring Observation Start Date	Number of Days Observed
2001	April 1	92
2002	April 1	92
2003	April 1	92
2004	April 20	72
2005	April 12	80
2006	April 5	87
2007	May 11	51
2011	April 20	72
2012	April 4	88
2013	April 19	73
2016	April 11	81
2018	April 9	83
2019	April 9	83
2020	April 6	86
14 Years of data	Average Start Date April 9*	1,132 observation days

*excludes years without data and the late start in 2007 on May 11th.

III. Analysis

a. Effects of River Flow (Stream Discharge) on Fish Passage Potential

Flow data, measured in cubic feet per second (CFS), is derived from the USGS Gauge 01208500 located at Beacon Falls, CT. The following passage from the 2003 *Kinneytown Evaluation Study* (page 6) identifies a flow of 500 cfs as the point where water overtops the spillway and creates false attraction in the bypass reach:

> *Bypass Reach*
>
> Migratory fish ascending the river may be attracted to the bypass reach rather than the fishway entrance during periods of discharge over the spillway. It appears that water begins to flow over the dam into the bypass reach at discharges of approximately 500 cfs. Very few fish successfully ascend the fishway during these flow conditions (Figures 2 and 4). Discharge over the spillway occurred during 45% of the 2001 spring season and 24% of the 2002 spring season. No fish successfully ascended the fishway during the evaluation period at stream discharges greater than 1,000 cfs.

In order to understand the frequency of false attraction based on this assumption, it is useful to visualize discharge graphs depicting flows during the spring migration (Figure 1).

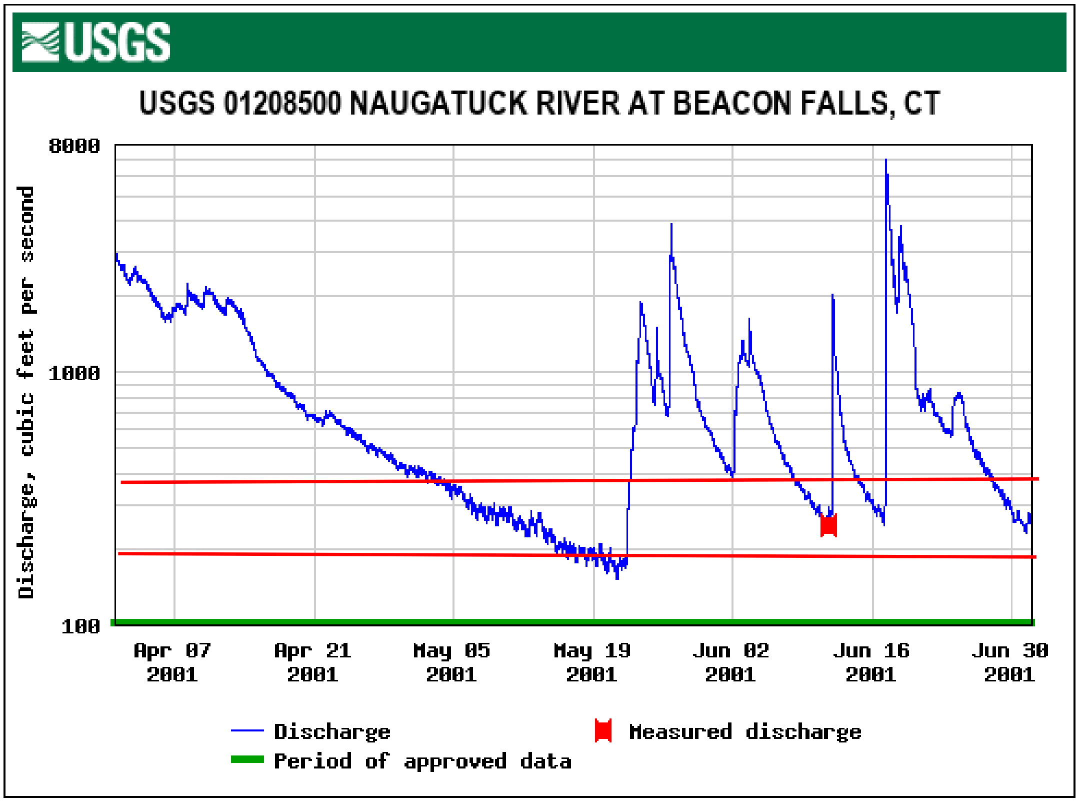


Figure 1. USGS generated discharge records from Beacon falls, CT with the red lines indicating flows above 200 cfs and below 500 cfs identified as the point where the spillway can activate due to lack of power generation or excessive discharge, respectively. The area in between the lines indicates optimal flow conditions.

CTDEEP did not evaluate fish passage during March likely due to many years of data showing no early presence of river herring. The initial start dates of fish passage counting by CTDEEP ranged from April 1 to April 16, with no observations in either 2009 or 2017.

For the purpose of this evaluation, we used approximately the same spring migration period that was used in the *2003 Kinneytown Evaluation Study (April-July)*. We collected overall discharge data from 2000 to 2020 during the reporting period from April 1 to July 1 (Figure 2). The decrease in average daily maximum flows is steady from the spring into summer. The daily fish passage data was paired with discharge from April 8 to May 18 to determine the passage conditions during the peak migration window.

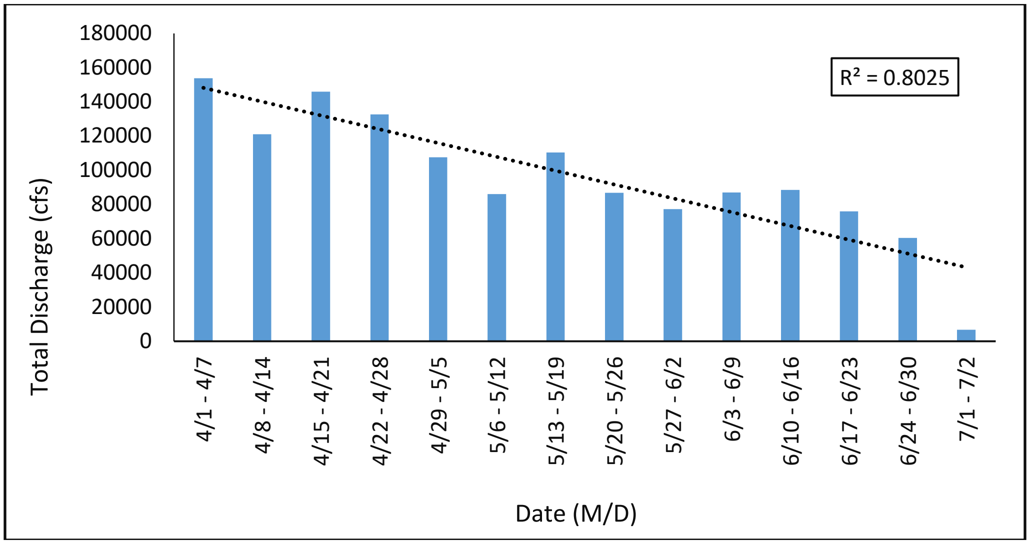
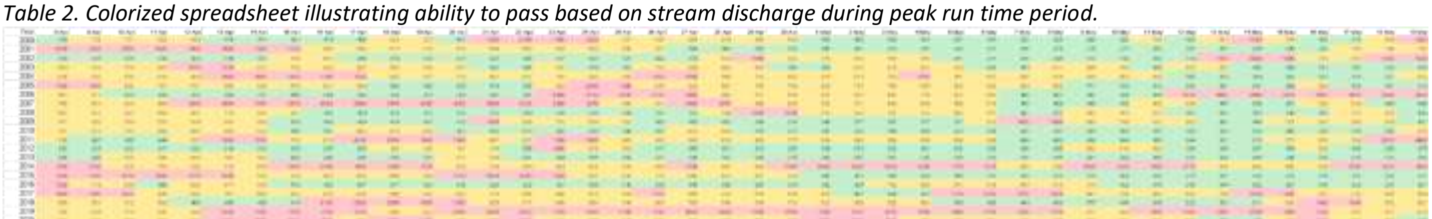


Figure 2. Cumulative discharge from 2001-2020.

b. Daily Mean Discharge during Peak Run Time from April 8 to May 18 (2000-2020)

In order to view the past twenty years of discharge data, it is helpful to use a colorized spreadsheet to observe seasonal patterns (Table 2).

Table 2. Colorized spreadsheet illustrating ability to pass based on stream discharge during peak run time period.



The colors in the spreadsheet relate to break points in flow identified as limits to fish passage described in the *2003 Kinneytown Evaluation Study* (red: $\geq$1000 cfs; orange: <200 and >500 cfs; green: between 200 and 500 cfs). The Study states that few fish can use the fishway at flows in excess of 1000 cfs indicated in red, and attraction problems begin to occur at 500 cfs as water flows over the spillway causing fish to swim past the entrance to the fish ladder and head into the bypass reach indicated in orange. The majority, 61%, of successful fish passage observations occurred during flows between 200 cfs and 500 cfs and 96% of fish passed between 100 and 900 cfs.

c. Daily-Fish Passage Analysis

Daily fish passage data was provided by CTDEEP for 14 of the 21 years beginning in 2000. Daily fish passage can be compared to daily high discharge readings. In order to determine the best period to analyze, it was necessary to choose the evaluation year that had the greatest number of flow days that were conducive to fish passage coupled with ladder use. This generates a peak run time that can be narrowed with subsequent annual data sets. The intent is to look at flows when it is more likely that fish are in the river and trying to ascend the ladder.

The longest period during the 2003 Study when flows were conducive to fish passage (60%) occurred in 2002. During this period, alosine and gizzard shad use of the fishway was observed sporadically between the beginning of the second week of April and mid-June, with a large number of days spread throughout the period where optimal passage flows occurred in sequence. The assumption was made that the majority of fish in 2002 encountered passable days with the exception of mid-May. The same pattern held true when all fish species observed at the ladder were combined (Figure 3). This suggests that, for the purposes of this analysis, cumulative species data is more valuable for assessment inasmuch as alosine numbers alone are too small for meaningful assessments of ladder usage. However, the ladder was designed for the target species which are American shad, sea-run trout, blueback herring and alewife and was not engineered specifically for other species.

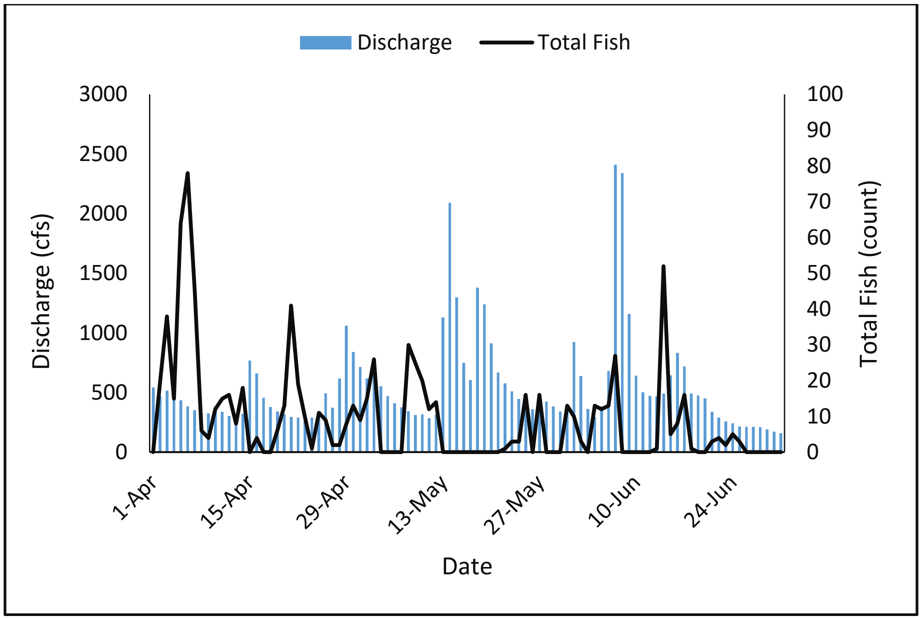


Figure 3. Fish run timing spread out over the migration season with frequent optimal flow events in 2002.

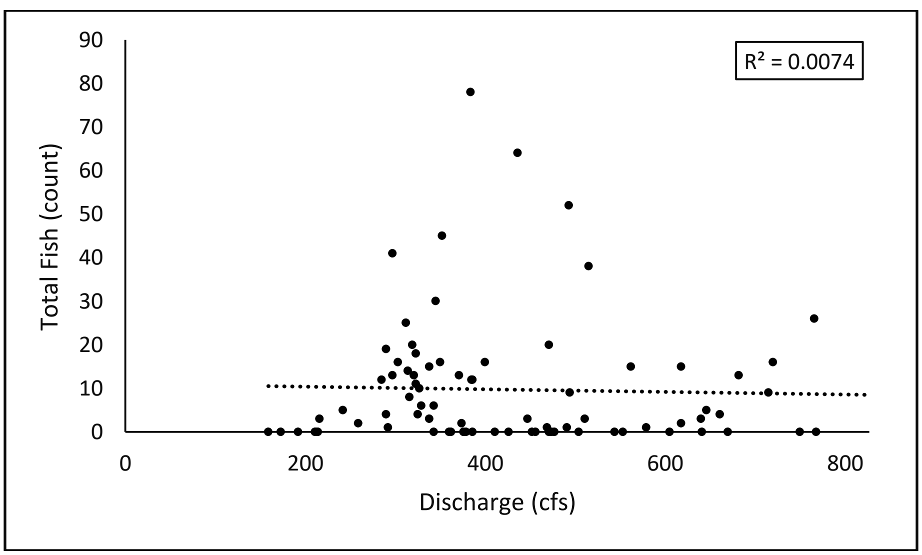


Figure 4. Scatterplot of stream discharge to daily fish passage counts in 2002.

The fish passage data depicted in Figure 4 is difficult to parse given the number of optimal flow days in both frequency and of sequentially passable days, as well as the overall spacing of these periods across the entire migration season that occurred in 2002, resulting in a small R^2 of 0.0074.

However, when this same data is binned to 100 cfs increments of discharge, the pattern indicating preferred flow usage is easier to detect (Figure 5).

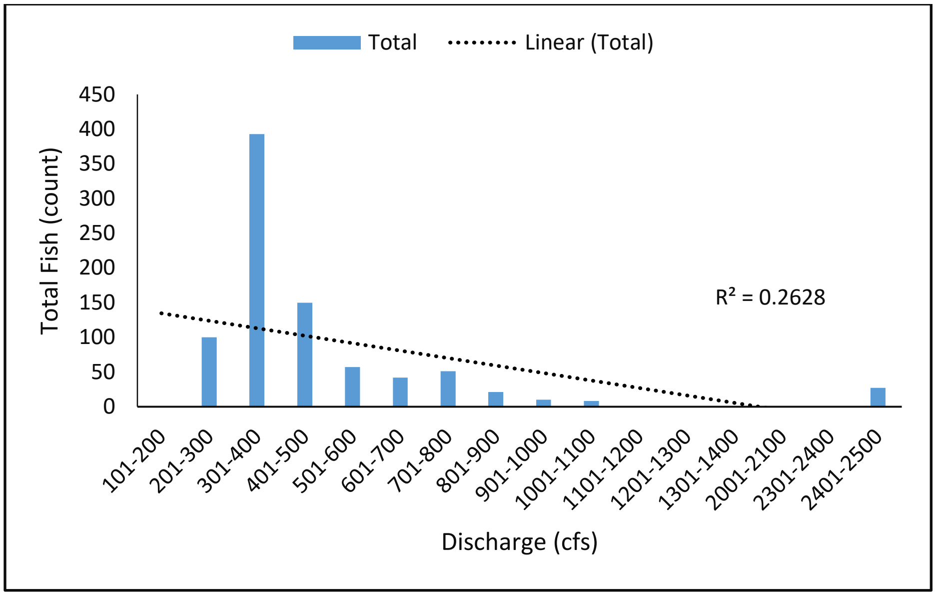


Figure 5. Stream discharge binned in 100cfs increments indicating preferred discharge ranges for ladder usage (2002).In 2006, 27 lamprey ascended during flows between 2401-2500 cfs.

There is a clear pattern of essentially no fish passage below 200 cfs and a rapid decline after the 500 cfs mark. This pattern holds true both before and after the Ansonia Unit shutdown occurred. A summary of annual discharge to daily fish passage graphs are provided in the appendices of this report**.**

a. Annual Cumulative Assessment of Stream Discharge to Daily Fish Counts

The seasonality of ladder usage is indicated in Figure 6, which utilized binned totals by week to smooth variation of flow on any individual day. The bulk of the fish usage (75%) for all years occurred between April 8 and May 19, coinciding with river herring runs, as well as migrations of sea-run trout and white suckers. Fish passage during this time period is essential for meeting restoration goals and overall ecological function of the other river species.

Usually, high flows and cold temperatures are limiting factors in early spring, and low flows and hot temperatures become limiting factors in late spring. The following table shows fish use by week with a gradual downward trend over the season, but the average CTDEEP video observation start date is April 9, so less data is available for the first week.

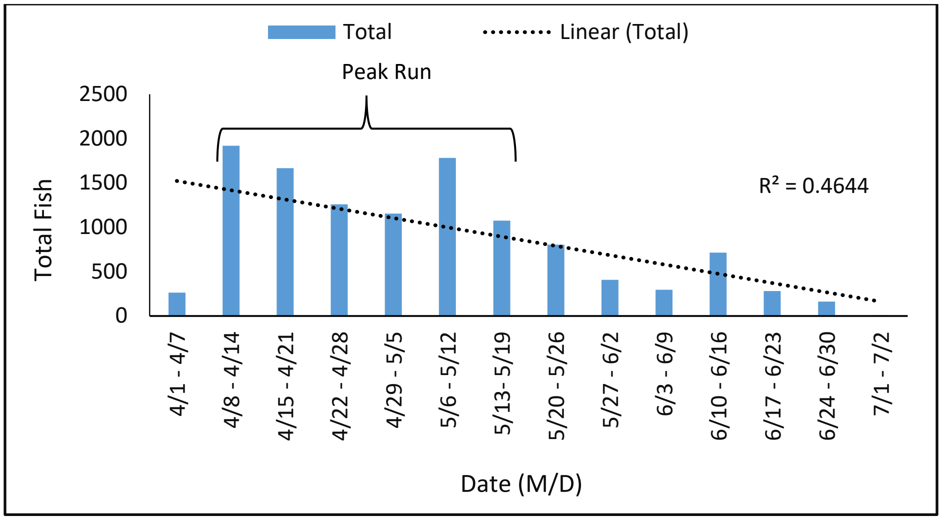


Figure 6. Cumulative weekly ladder use from 2001-2020.

Table 3 describes the number of optimal flow days and cumulative fish passage utilizing the time period during which 75% of observed fish passage occurred, spanning from the first week of April to the third week in May.

Table 3. Days of optimal flow conditions during peak migration period from April 8th to May 19th (2000-2020 cumulative).

Year	Days of Optimal Flow 200 to 500 cfs	% Optimal Passage Flow	Total Fish/year	% Passage days low to high
2000	20	48%	390	0%
2001	20	48%	1105	0%
2002	26	62%	859	7%
2003	15	36%	*1156	7%
2004	7	17%	*2688	17%
2005	15	36%	1692	21%
2006	18	43%	*1579	26%
2007	9	21%	945	33%
2008	20	48%	803	36%
2009	19	45%	No data	36%
2010	29	69%	419	43%
2011	11	26%	414	45%
2012	31	74%	1038	45%
2013	35	83%	857	48%
2014	0	0%	323	48%
2015	19	45%	177	48%
2016	29	69%	178	62%
2017	3	7%	No data	69%
2018	14	33%	176	69%
2019	0	0%	151	74%
2020	3	7%	72	83%
Total	343	Avg. 39%	11,791	NA

For the 21-year record of discharge data represented in Table 3, the average percentage of days below the 500 cfs mark was 51%. By focusing analysis on the peak run timing determined by aggregating all fish counts, the percentage decreases to 50%. By including the lack of fish passage below 200 cfs, the average number of passable days falls to 39%. Therefore, on average, during 61% of the peak migration season, water spills over the dam into the bypass reach, initiating false attraction and potentially decreasing the function of the fish ladder. This is a similar conclusion reached by DEEP staff in the *2003 Kinneytown Evaluation Study*. The trend of both passable days and total fish numbers has been downward during the two decades analyzed (Figure 7), however the standard variation exceeds the mean so confidence is low. From 2009 to present, with the exception of 2013, fish passage has been reduced regardless of the number of passable flow days (Figure 7). This may be a result of overall lower numbers of fish in the river, the timing and degree of flow impairments, or other suboptimal passage conditions.

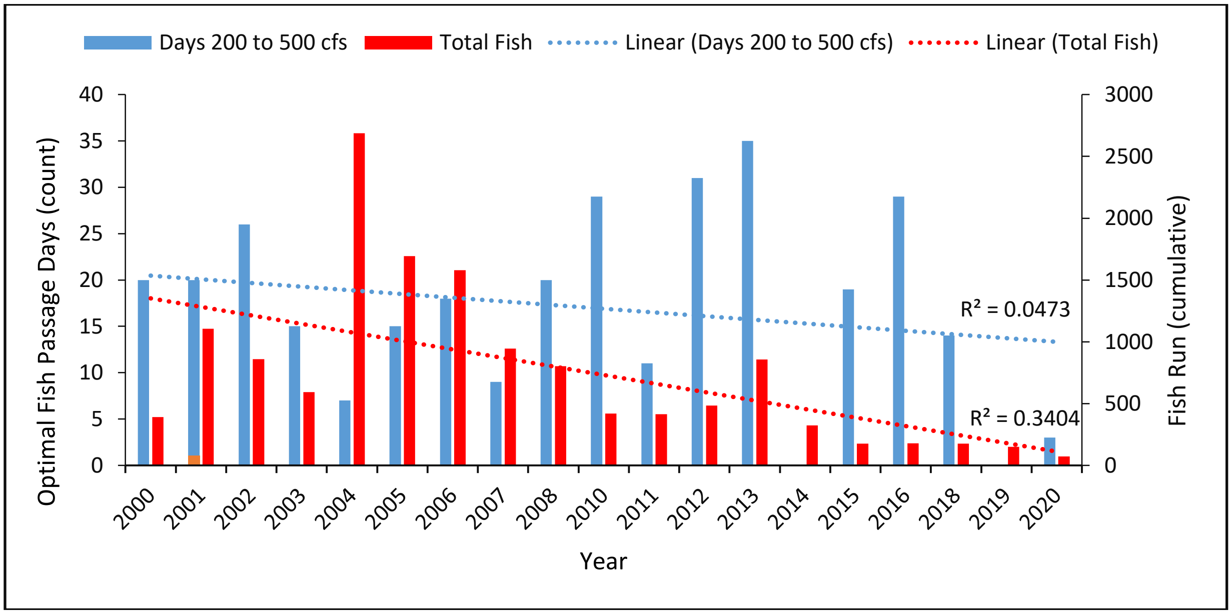


Figure 7. Optimal fish passage days out of a possible 92 days compared to annual cumulative species fish passage (2000-2020).

a. *Alosa* Usage

To look for a relationship between flow rates and river herring fish passage run strength, annual run accumulations for gizzard and American shad were combined with blueback and alewife from April 1 to July 1. These numbers were then run against the number of days where discharge was below 500 cfs and above 200 cfs from 2000 to 2019 (excluding 2009 and 2017 when no fish counts were conducted) (Figures 8 and 9).

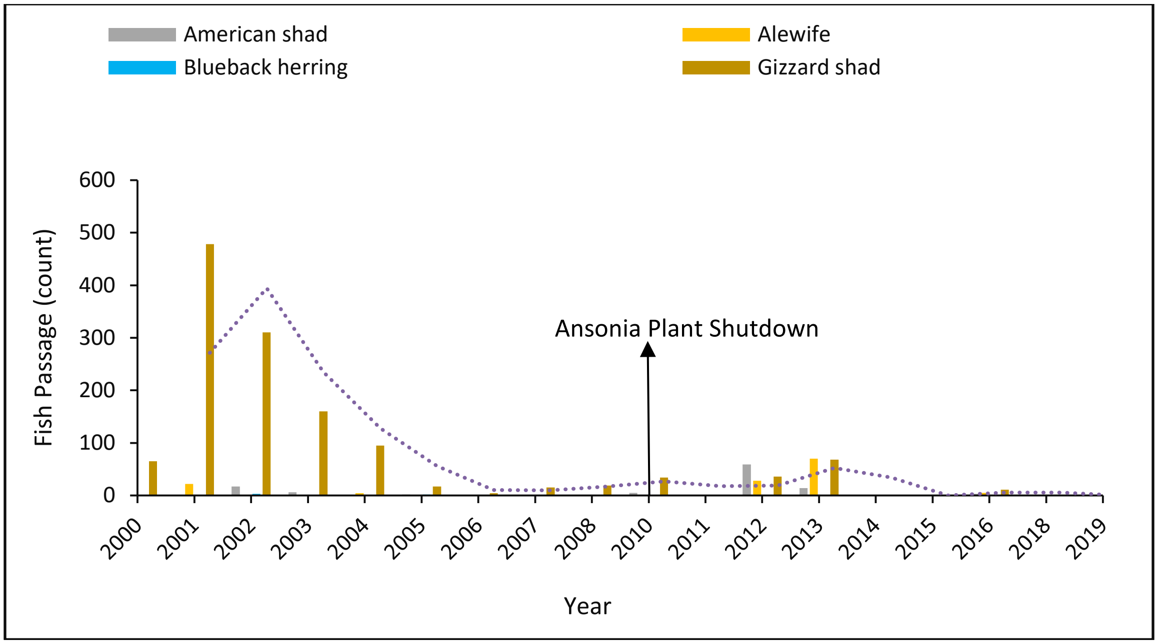


Figure 8. Two year moving average of Naugatuck alosine ladder use (2000-2019).

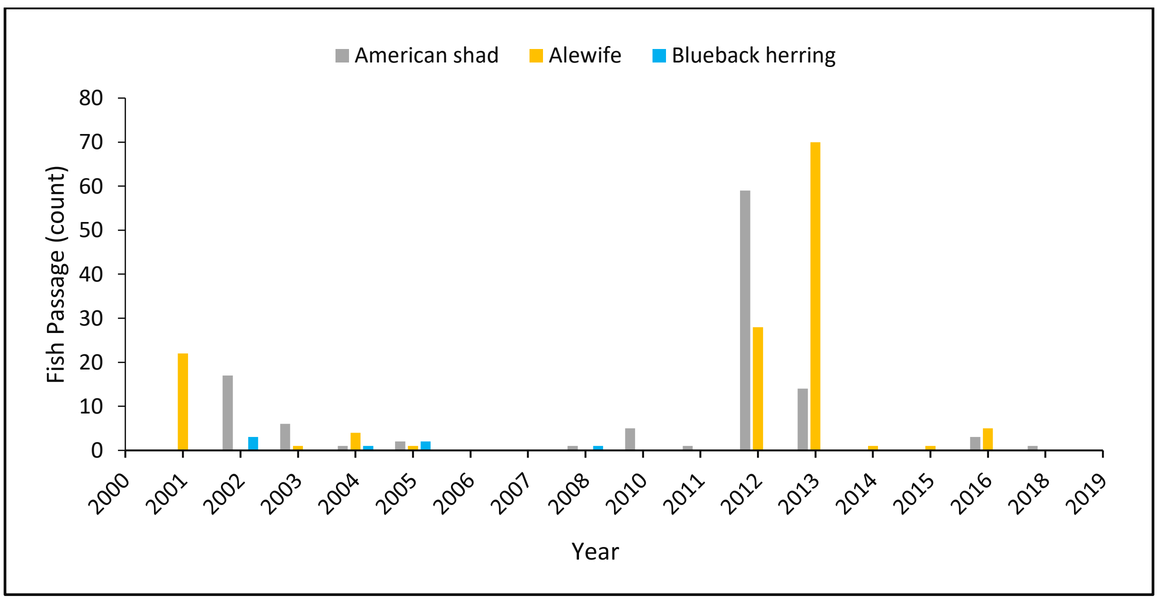


Figure 9. Naugatuck alosine use for American shad, alewife, and blueback herring (2000-2019).

The total counts include the full numbers for fish run versus peak run timing as daily data was not available for 2000, 2008, 2009, 2010, 2014, and 2017. The runs are all minimal with no discernable pattern.

b. American Eel and Lamprey Passage

i. American Eel *(Anguilla rostrata)*

Eel Passage numbers were not consistently recorded during the *2003 Kinneytown Evaluation Study*, as they were not a target species during fish passage construction and assessment work.

The Study recommended establishing an eel ladder which was done, though not a requirement under the FERC license. Given the limited resources of CTDEEP staff the eel ladder has been operated sporadically over time (K. Zak, Personal Communication, 2021). NRRG has documented that there are significant numbers of returning elvers attempting to ascend the river (Figures 10, 11, and 12).

Figure 10. Elvers amassing below western side of the dam.

Figure 11. Elvers attempting to climb dam at night.

Figure 12. Elvers unsuccessfully climbing bypass door.

ii. Sea Lamprey (*Petromyzon marinus*)

According to fish ladder observations, sea lamprey presence at Kinneytown Dam is relatively recent. In 2004, one lamprey was observed passing the ladder for the first time and 63 lamprey were transplanted above the Kinneytown Dam. In 2005, CTDEEP observed five lamprey using the ladder and another 110 were transplanted upstream. Larger numbers of lamprey began passing the dam site beginning in 2006 though the overall trend is downward (Figure 13).

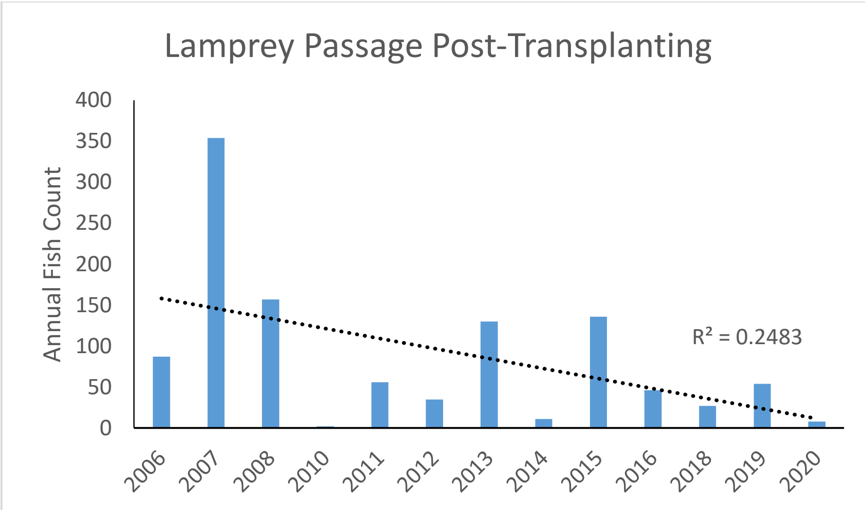


Figure 13. Annual lamprey counts at Kinneytown Dam fish ladder video counter

It is not uncommon to see lamprey attempting to ascend the face of the dam in the spillway (Figures 14 and 15).

Figure 14. Several lamprey attempting to ascend spillway 5/2021. Figure 15. Lamprey attached to the dam face 5/2021.

Lamprey have been observed in recent years becoming trapped when the bypass channel dewaters (see Figure 16). It is possible, but highly unlikely, that they spawned prior to dying. However, the high velocities preclude spawning gravel accumulation below the dam and any gametes released would be transported downstream and not deposited in the gravel of a nest.

Figure 16. Dead lamprey in the bypass channel after dewatering.

IV. Discussion

Our analysis of fish ladder usage in relation to stream discharge shows that more individuals of certain species have been visually observed and video recorded below the dam in recent years then are recorded on the CTDEEP fishway video (see NRRG video: [Hydroland Kinneytown Dam: The state of affairs at Kinneytown Dam - YouTube]). A clear finding is that the passage is compromised by river discharge for an average of 61% of the time during the peak spring run period and a significant number of fish are not passing the dam. Passage is compromised by both excessive flows down the fish ladder as well as false attraction to the dam base from water spilling over the dam. This congregates fish away from the entrance to the fish ladder. The period analyzed indicated that high flows dominated the majority of the peak migration time which resulted in passable flows 39% and impassable flows 61% of the time from April 8 to May 19 (Table 3). Given that the Naugatuck is both a long and fast river, initial entry of river herring, as well as spawning times, may be different than those of other CT systems that are shorter and less steep. Runs of river herring species may contain an earlier run component when fully restored so it is important to think about passage design that can function at higher flow rates typical in early spring (Figure 2).

Given that the finding that 39% of the days are passable during peak migration is an average and is based on variable discharge rates: the efficacy of the ladder can drop to 0% on any given year based on suboptimal flows during peak migration timing. Further analysis on interannual flow averages and temporal impacts (e.g., multiple poor passage years in sequence and elimination of year classes) is warranted and may help explain some of the variations in annual fish passage numbers. Many other factors also determine run strength, especially spawning stock recruitment rates and fishing bycatch rates, which are currently unknown on a watershed level scale. Aside from environmental variables affecting spawner recruitment, both the passage efficiency and mortality rate for downstream juveniles passing the dam site is also unknown, as well as the impact of turbine operations on the number of days when false attraction occurs.

Unfavorable discharges over several weeks during peak migration could result in the complete elimination of year classes of alosine species and may partly explain the years where no herring are passing. Year class losses are extremely disruptive to rebuilding stocks (see Figures 6 and 7) and can reduce the resilience of runs exposed to other pressures, such as unfavorable climate conditions, pollution, and bycatch.

The overtopping flow of 500 cfs identified in the *2003 Kinneytown Evaluation Study* occurred during the period when significant amounts of flow were being redirected down the bypass channel to the Ansonia Unit. Once the Ansonia Unit was shut down it is probable that a different and likely lower flow rate would trigger spillway activation. When the entire 21 years are combined, the analysis identified 474 cfs as the point where passage efficacy likely begins to drop. There have been varying reports on when the Ansonia plant was shut down but passage numbers since 2014 have been extremely low. This has been the case even with years of above average optimal flow days (Figure 7). Currently the primary turbine (Unit 1) is also shutdown which has resulted in a constant flow over the spillway resulting in continuous false attraction for the entire period beginning in the fall of 2020 until present (see Figures 17 and 18), (FERC Filing - 20210712-5068_2021.07.12 STS NRRG Comments P-6985-005).

Figure 17. Spillway - Beacon Falls USGS Gauge 209 cfs. June 2021.

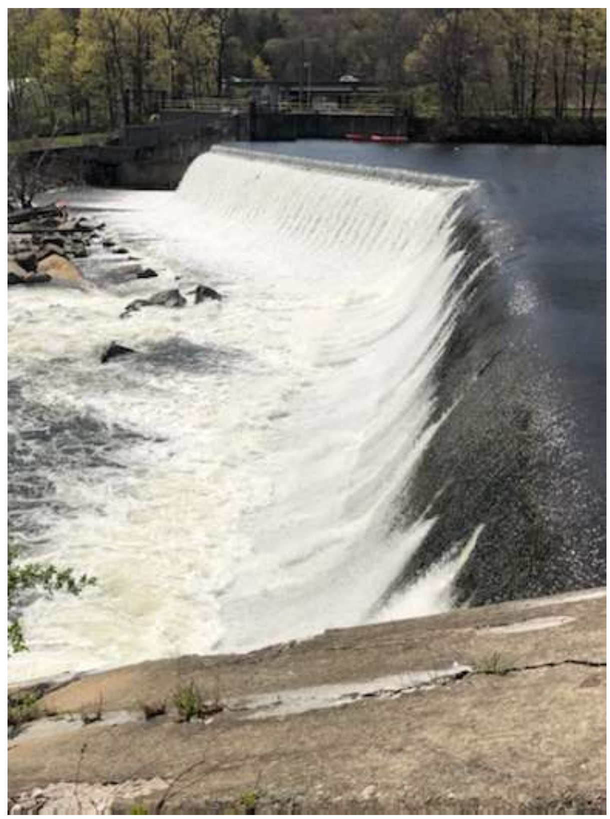


Figure 18. Spillway - Beacon Falls USGS Gauge ~629 cfs. May 2021.

Given the overall low fish passage returns since the ladder was installed and the lower returns since the Ansonia Unit went offline (Figure 8), the Naugatuck diadromous fish runs have not been strong enough to begin rebuilding to reach the restoration goals. Shad are known to live from 6-10 years, with 3-5 years at sea, and blueback herring up to 8 years, with approximately 6-7 years at sea (Loesch 1987), therefore run rebuilding can take two or more decades to reach. As outlined in the Naugatuck River Restoration Plan, the Naugatuck River's restoration potential is high. Millions of public dollars have been spent on dam removal, habitat enhancement, sewage plant upgrades, and state of the art fish passage upstream from the Kinneytown facility. Though the numbers from the plan have been revised downward recently for the GE settlement project scoping, the CTDEEP has identified the potential size of future populations to produce average annual runs of around 50,000 American shad and river herring, as well as sea run trout, eels, and striped bass. However, from 2014 to 2019, only 25 individuals were counted as passing the fish ladder from all of these species. For the entire period from 2000-2020, only 250 individuals combined of American shad, blueback herring, and alewife passed. Not counting an additional 1,313 gizzard shad, this is an average of 12.5 target species individuals per year passing through the ladder, when the combined target is 50,000+ per year twenty years after restoration efforts began.

Spill events result in regular false attraction of multiple species into the bypass reach. Fish that end up in this channel may return to the fishway and ascend, but this return to the fish ladder entrance is not documented in the *2003 Kinneytown Evaluation Study*. However, the study does document blueback herring below the dam with no records of the species passing through the ladder in the same year. An environmental DNA (eDNA) study was conducted in 2021, to document anadromous fish presence below the dam to compare with video counts in the ladder. Blueback herring were detected with no records of any blueback herring passing the dam (Jonah Ventures, Boulder, CO 2021). These two records indicate that the passage design may not be conducive to passing blueback herring despite them being a restoration target species. Save the Sound and Naugatuck River Revival Group also documented significant predator pressure as the water levels drop in the channel, as well as outright stranding occurring when the bypass channel dewaters (FERC Filings - 20210712-5068_Attachments B-F – Affidavits; 20210712-5068_2021.07.12 STS NRRG Comments P-6985-005). These anthropogenically caused mortality events have the potential to occur multiple times in an average year depending on turbine operations and discharge. Given the inter-diel flow variance and potential effects of power generation, the true bypass mortality rate is unknown.

V. Analysis of Other *2003 Kinneytown Evaluation Study* Observations

a. Power Generation vs Non-Generation Usage of Fish Ladder in Relation to Stream Discharge and Water Elevations for 2002.

As described in the *2003 Kinneytown Evaluation Study*, from April 11 to April 15 of 2002, fish were found to pass up the ladder while the spillway was active. However, the data specifies that power was not being generated from April 11 to April 13 (Table 4). During this non-power generation period, 40 gizzard shad were able to ascend the ladder, even as water was spilling into the bypass reach. Although this is one observation period and the data was not available for other years, it does indicate that the ladder may be affected by inconsistent management of flashboards and baffles which can affect the depth and therefore the force of the water within the fish ladder itself. Also, this occurrence may suggest that fish passage can be compromised by more than just the false attraction posed by the spillway drawing fish into the bypass reach. However, it should be noted that an unknown variable was the volume of the spill water during this period and its ability to wet the bypass channel enough to attract fish.

Head pond elevation seems to be a key driver of fish ascending the ladder regardless of whether the power being generated or not during normally optimal flows in this small sample size (Table 5).

Table 4. Species observed using the ladder during spillway activation and turbine usage from April 11-15, 2002.

Date	Smallmouth	White Sucker	Atl. Salmon	Gizzard Shad	Power	CFS
April 11	4	4	0	8	No	338
April 12	1	0	0	17	No	303
April 13	0	0	2	16	No	316
April 14	0	0	0	0	Yes	323
April 15	0	2	0	2	Yes	768
April 16	0	0	0	0	Yes	661
April 17	0	0	0	0	Yes	456

Table 5. Facility elevations April 11- 17, 2002. Source CTDEEP.

Date	Head Pond Elevation	Fishway Elevation	Tailrace Elevation	Spillway Activity noted
April 11	54'3"	48''3"	21'3"	heavy
April 12	54'3"	48''3"	21'3"	heavy
April 13	54'3"	48''3"	21'3"	heavy
April 14	54'3"	48''3"	21'3"	heavy
April 15	54'3"	48''3"	21'3"	heavy
April 16	54'11"	48''3"	21'9"	heavy
April 17	54'10"	48''3"	21'9"	heavy

Water surface elevation (WSE) in the head pond ranged from 54’2” to 54’ 11”, and ranged from 48’2” to 48’ 3” in the fishway exit pool. Tail race elevations were either 21’3” or 21’9” during the monitoring period. Higher head pond and tail race elevations appear to negatively impact fish passage as well as false attraction, however since head pond and tail race elevations were not measured regularly with the exception of 2002, it is useful to note that higher fishway elevations are typically associated with greater discharge, though not consistently.

a. Temperature

In 2002, temperature gradually increased over the evaluation period from 12° C to 24° C (Figure 19). From April 11 to 13, 2002 no power was generated and stream discharge was moderately low (316-338 cfs). Water temperature increased briefly during this time possibly due to a period of light precipitation, shallower river depth, and slower river velocities increasing residence time in the head pond allowing for more thermal absorption. When the turbine was not in operation all water discharged was surface water.

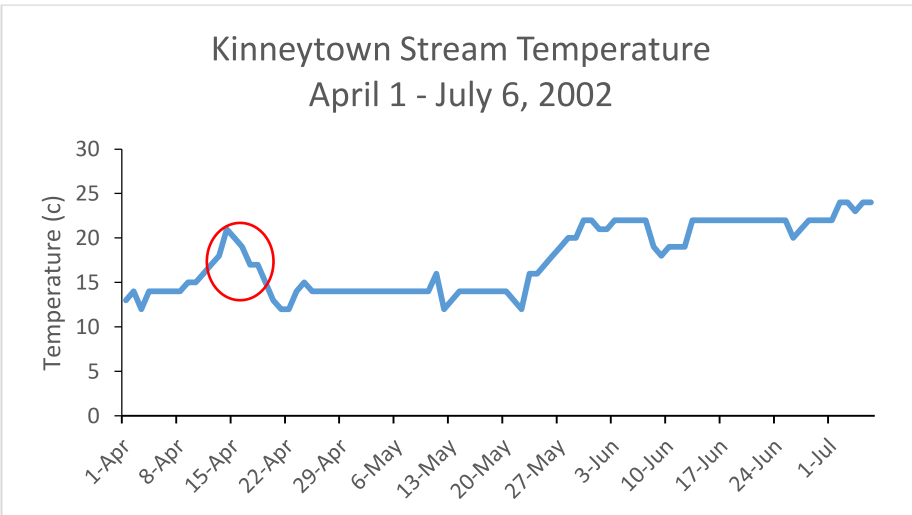


Figure 19. Stream temperatures from 2002 with early spring increase during moderate flows and no power generation.

b. Resting Pool Detections

An observation made on April 10, 2002 detected white suckers (*Catostomus commersonii*) in the resting pool. On April 10, 30 white suckers were detected in the ladder, and seven days later, another 13 were observed. Between April 10 and April 17, 11 white suckers passed the fish ladder. Lastly, from April 18 to May 7 (20 days), an additional 9 passed—with no further observations for the remainder of the season ending on July 1.

White suckers are a useful tool for determining the Kinneytown ladder usage as the numbers of fish using the ladder are consistently the highest across the two decades of data. The ladder is not explicitly designed for this species, but offers information that not all of the fish entering the ladder ascend.

VI. Recommendations for Future Investigations

a. Monitoring Both Upstream and Downstream Passage

It is the practice of Save the Sound to install fish traps for monitoring alosine species in CT by early March (J. Vander Werff, Personal Communication, 2021), prior to when river herring runs typically start since small numbers can show at the very beginning of the migration if temperatures and flow are conducive. This ensures the entirety of the run is observed, which is also critical as longer run times can lead to higher degrees of spawning success within the population. Indeterminate spawners, such as alewife, can use a wide range of spawning times after entering freshwater. This life-history strategy increases the chances that any given batch spawn will hatch into favorable environmental conditions for survival; however, delayed migration, while not related to spawning time duration, due to stream flows, temperature, or obstructions can increase exposure to predators (Rosset et al., 2017). In rivers with remnant or extirpated runs that are in the process of restoration, such as the Naugatuck River, increased predation due to extended residence time could be an additional factor impeding successful reestablishment. There have been periodic stocking events by CTDEEP (T. Wildman, personal communication, April 2021) that have not resulted in run restoration. Researchers at UCONN-Storrs are currently looking at juvenile outmigration success rates based on some of these variables.

One additional consideration for increasing the fish ladder observation time range is the impacts of warming water temperatures, which influences both run timing and spawning behavior. Since the 1970s, stream temperatures, which trigger alewife run timing at a threshold of 13°C, now occur on average 12 days earlier—with run initiation occurring 13 days earlier (Ellis and Vokoun, 2009). Therefore, the duration of fish ladder video operation may need to be adjusted to capture these shifts in migration timing.

b. Downstream passage

The *2003 Kinneytown Evaluation Study* mentions that when water is overtopping the spillway, young of year (YOY) are not attracted to the downstream bypass channel and are likely going over the spillway. In 2000 and 2001, power was not generated at the Kinneytown plant due to flow requirements and drought conditions, which activated the spillway for the outmigration season. Mortality of juvenile alosines travelling over spillways is not well studied. Mortality and increased risk of injury to river herring from passing through or over hydroelectric infrastructure relative to controls were characterized as 127% to 144% over control groups in a 2020 review of mortality studies (Algera et al. 2020). However, the number of studies was low and focused on turbine interactions. The Naugatuck River can experience very high velocities during fall flooding as juveniles outmigrate, as well as low flows, which both activate the spillway, discharging onto a cement apron and large rock substrate.

An improved method for evaluating downstream success rates should be designed beyond popping surveys, which observe YOY breaking the river surface as they migrate downstream. These methods should address both downstream migration rates of post spawning species such as shad that are iteroparous (repeat spawners) and to evaluate the YOY mortality either by passing over the spillway or through the turbines. Additional information detailing upstream stocking numbers and dates would inform both spawner recruitment and potential annual downstream YOY migration.

VII. *2003 Kinneytown Evaluation Study* Recommendations

The *2003 Kinneytown Evaluation Study* makes the following recommendations that were not followed. (Recommendations in italics.)

- *KHC continues to operate the fishway, annually, in the manner it was operated in 2002.*

It is unknown the frequency of turbine operation over the past two decades though the Ansonia Unit has been inoperable for 10 years and Unit 1 has been out of operation since October 2020.

- *The Inland Fisheries Division (Division) and the Kinneytown Hydroelectric Company, Inc. (KHC) enter into an agreement that provides future access to the fishway for the Division so that the video imaging system can continue to operate and collect valuable data.*

This recommendation has been followed and, though a few years were not monitored, the video fish counts have provided several years of data for this analysis.

- *The Division continue to monitor the bypass reach as part of its continued access to the site and if deficiencies are noted, the Division and KHC cooperatively address them & the KHC and the Division be mindful of the problems of false attraction and stranding in the bypass reach and explore ways of reducing them in the future with either operational or engineering solutions.*

Given that the false attraction problem described in the 2003 Study still exists today, it is clear that KHC did not cooperatively address problems with CTDEEP. To our knowledge, CTDEEP reached out over recent years to attempt to address the issues of false attraction, but no action, beyond inconsistent flashboard placement, was taken by KHC (Personal communication K. Zak).

- *The Division and KHC work cooperatively in 2003 to install an inexpensive, effective upstream eel passage to expedite the restoration of the eel population on the Naugatuck River upstream of the Kinneytown Dam.*

An eel passage was constructed but, at least in recent years, has not been consistently operated due to resource constraints at CTDEEP.

To fully understand what future recommendations should be made, a comprehensive efficiency study should be required to determine the number of fish migrating to the Kinneytown Dam site and the proportion of the fish that ascend the ladder, with full access to flow data at all discharge points including the turbine, spillway, bypass, and fishway. In addition, a downstream assessment would identify species and the numbers of both adult spawners successfully returning to saltwater, as well as the young of year out-migrants and the mortality rate from passage through the various discharge points at the Kinneytown facility.

VIII. Conclusions

This is a brief and general assessment of the *2003 Kinneytown Evaluation Study* and subsequent fish passage data combined with local observations. We are fortunate that CTDEEP collected this information as a baseline to inform current management decisions in the face of shrinking staff and budget constraints. While the ladder can pass some fish, it is unknown as to how efficiently it passes fish throughout any given migration season due to variable stream discharge rates and inconsistent turbine operations as well as head and tail race elevations. Given that the facility typically begins having passage problems at river flows exceeding 500 cfs and below 200 cfs, and the fact that these poor passage flow conditions have occurred on average 61% of the time during peak migration over the past two decades, it is likely that overall fish passage efficiencies are poor and eel passage is nonexistent during years when the eel ladder is not operated.

Current redirection of additional flow over the face of the dam, instead of through the Ansonia Unit bypass channel, has also exacerbated ineffective passage conditions. However, this review illustrates that problems were also evident prior to the unit shutdown and specifically highlighted in the *2003 Kinneytown Evaluation Study*. We were informed that the shutdown of Ansonia occurred in 2010.

It can take several years to reach sustainable spawning biomass after a dam is removed. With the current fish passage conditions resulting in inadequate passage rates the restoration goals set out in the *Naugatuck River Restoration Plan* are likely unattainable. This is especially true in the case of blueback herring which were documented below the dam twice with no individuals passing the ladder during the corresponding year’s migration. New designs should be explored and encompass effective upstream and downstream passage with consideration to all species inhabiting the river, including the catadromous American eel. With continued stocking efforts from CTDEEP and modern, safe, timely and efficient fish passage standards applied to the Kinneytown facility the restoration could be successful and the time frame could be considerably shortened.

References:

Algera, D.A., Rytwinski, T., Taylor, J.J. *et al.* What are the relative risks of mortality and injury for fish during downstream passage at hydroelectric dams in temperate regions? A systematic review. *Environ Evid* **9,** 3 (2020). https://doi.org/10.1186/s13750-020-0184-0

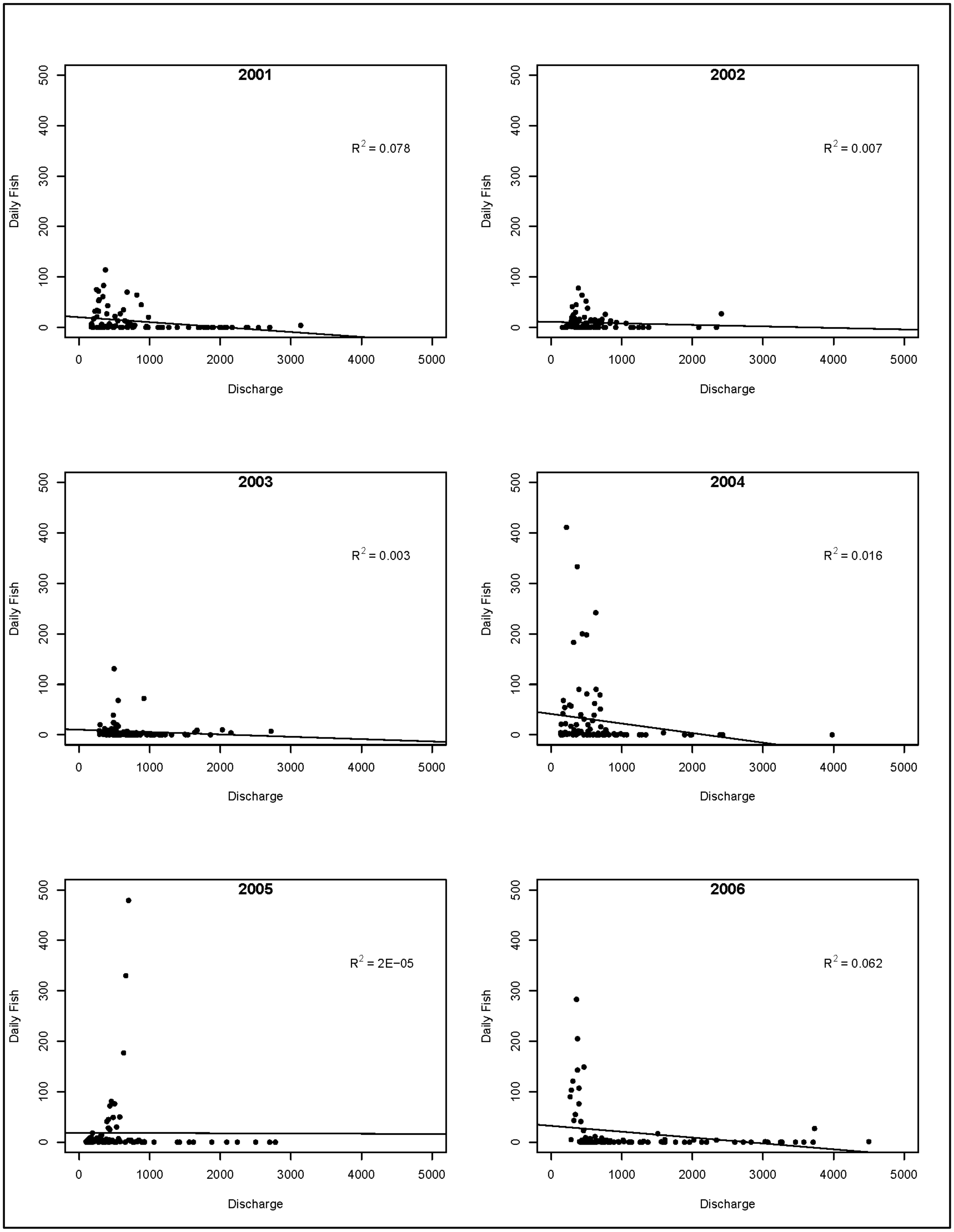
Davis, J.P. & Schultz, E.T. (2009). Temporal Shifts in Demography and Life History of an Anadromous Alewife Population in Connecticut. *Marine and Coastal Fisheries*, 1:1, 90-106, DOI: 10.1577/C08-003.1.

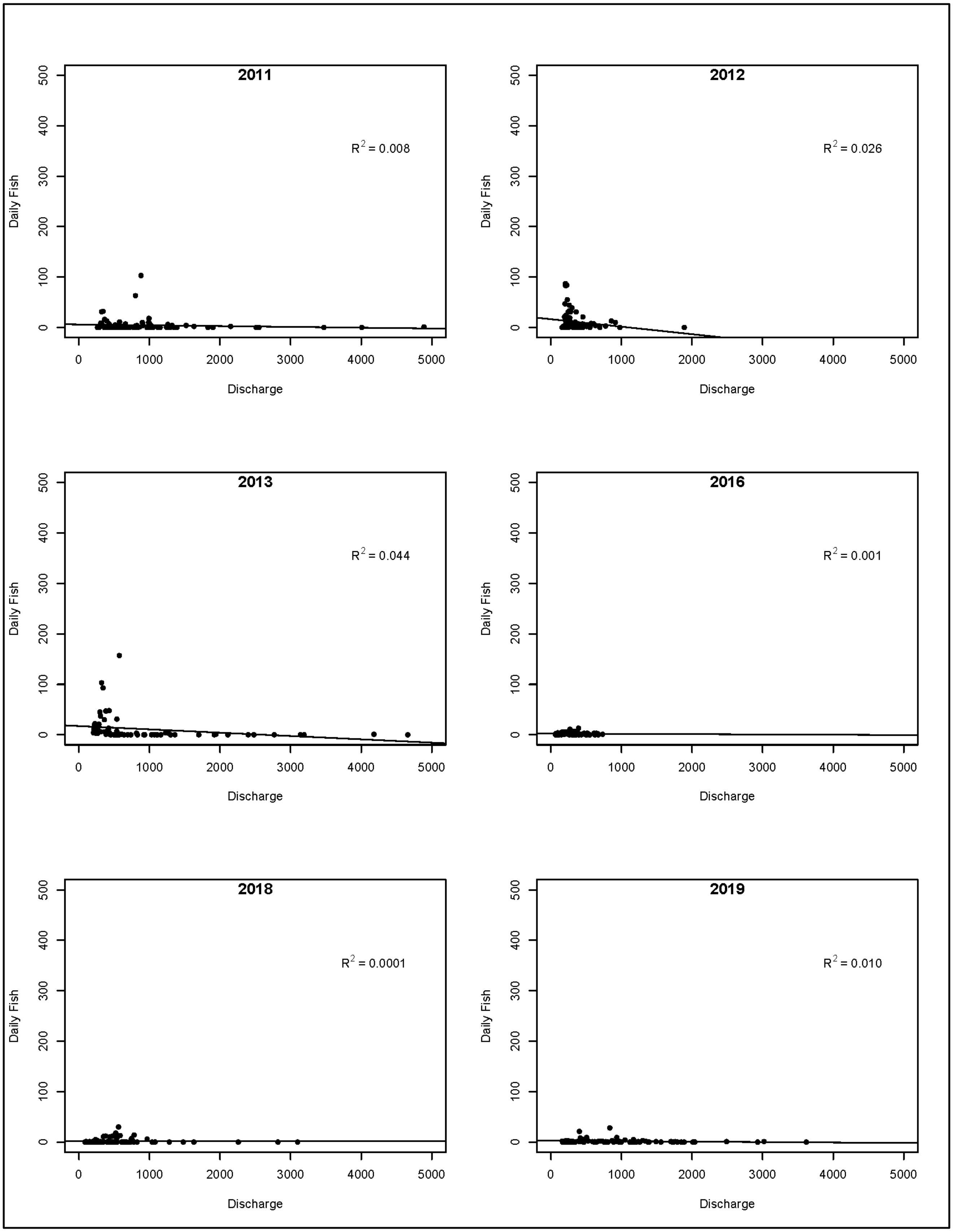
Ellis, D. & Vokoun, J.C. (2009). Earlier Spring Warming of Coastal Streams and Implications for Alewife Migration Timing. *North American Journal of Fisheries Management*, 29:6, 1584-1589, DOI: 10.1577/M08-181.1.

Loesch, J. G. 1987. Overview of life history aspects of anadromous alewife and blueback herring in freshwater habitats. In Common Strategies of Anadromous and Catadromous Fishes, pp. 89–103. Ed. by M. J. Dadswell, R. J. Klauda, C. M. Moffitt, and R. L. Saunders. American Fisheries Society Symposium 1, Bethesda, MD.

Rosset, J., Roy, A.H., Gahagan, B.I., Whiteley, A.R., Armstrong, M.P., & Sheppard, J.J. (2017). Temporal patterns of migration and spawning of river herring in coastal Massachusetts. *Transactions of the American Fisheries Society*. 146(6): 1101–1114.

Appendix: Annual Daily Fish Passage to Discharge




2011
$R^2 = 0.008$
2012
$R^2 = 0.026$
2013
$R^2 = 0.044$
2016
$R^2 = 0.001$
2018
$R^2 = 0.0001$
2019
$R^2 = 0.010$
Daily Fish
Discharge
0
100
200
300
400
500
1000
2000
3000
4000
5000